The Institute of Physics

BULLETIN

MARCH 1958 · VOL. 9 · No. 3

CONTENTS

NOTICES TO MEMBERS
Page 49

THE RECRUITMENT AND TRAINING OF PHYSICISTS
NORMAN CLARKE
Page 51

MEETINGS OF THE BRITISH NUCLEAR ENERGY CONFERENCE
Page 59

THE PHYSICIST IN THE INDUSTRIAL GROUP OF THE U.K. ATOMIC ENERGY AUTHORITY
L. ROTHERHAM and T. EDGE
Page 60

CORRESPONDENCE
Page 65

REVIEWS OF BOOKS
Page 67

FORTHCOMING INSTITUTE MEETINGS
Page 69

THE INSTITUTE'S JOURNALS
Page 70

The Bulletin is published by The Institute of Physics for circulation to its members.

Notices to Members

New Year's Honours List

Members will be glad to learn that three Fellows received awards in the New Year's Honours List. They were Dr. C. R. Burch (C.B.E.), Mr. W. J. Challens (O.B.E.) and Dr. J. F. Gillies (O.B.E.).

Accommodation Available

The Will of the late Mrs. Phillips provides for the tenancy and maintenance of a small self-contained flat in Welling, Kent, to be within the gift of the Committee of the Benevolent Fund of the Institute.

Any member (irrespective of age) who may be in need of this kind of assistance for a short or long period is therefore invited to make inquiries of the Secretary of the Institute.

Applied Spectroscopy Group : Meeting to be repeated

The Applied Spectroscopy Group held a meeting on " X-ray Fluorescence Spectroscopy " on February 21 at the Institute's House and the demand for tickets was much greater than the available accommodation. Many members were unable to obtain tickets and arrangements have therefore been made for the same principal speakers to read their papers again at a second meeting which will be held on Tuesday, April 1, at 3.0 p.m., again at the Institute's House. Admission will be by ticket only and application should be made as soon as possible to the Institute.

***Bulletin* Articles in Book Form**

The Deputy Secretary has been invited, as Editor of the *Bulletin*, to select some of the articles that have appeared in the *Bulletin* in the past few years, for publication in book form. Publication will be by Chapman & Hall Ltd., on behalf of the Institute, and it is hoped that the book will appear by the autumn of this year. Further details will be announced in the *Bulletin* later.

Committee on Postgraduate Training

The Institute and The Physical Society have set up a joint committee, under the Chairmanship of Professor N. Kemmer, to consider postgraduate training in physics with reference to the needs of fundamental and applied research. The membership of the committee is as follows :

Representing The Physical Society,

Professor N. Kemmer (*University of Edinburgh*)
Mr. J. A. Ratcliffe (*University of Cambridge*)
Dr. R. A. Smith (*Royal Radar Establishment*)
Professor D. H. Wilkinson (*University of Oxford*)

Representing The Institute of Physics,

Dr. J. N. Aldington (*Siemens Edison-Swan Ltd.*)
Dr. R. Beeching (*Imperial Chemical Industries Ltd.*)
Professor R. V. Jones (*University of Aberdeen*)
Mr. L. Rotherham (*U.K. Atomic Energy Authority*)
Professor J. G. Wilson (*University of Leeds*)

with Mr. N. Clarke as Secretary of the Committee.

Remission of Fees of members of long standing

Fellows and Associates over the age of 65 years who have been members continuously for at least 20 years are reminded that they may, if they so wish, have their future annual subscriptions remitted. They will continue to receive the *Bulletin* and notices of Branch and Group meetings and may have the *Journal of Scientific Instruments* and the *British Journal of Applied Physics* upon the same terms as are current for students ; at present this rate is one guinea for each journal. Those who wish to take advantage of this ruling should notify the Secretary.

Einstein Memorial Lecture

On November 15, 1957, the South Australian Division of the Australian Branch of the Institute held the first of a series of annual lectures which have been named the " Einstein Memorial Lectures." The lectures commemorate Einstein's name by bringing before a public audience an eminent scientist to discourse on a recent development in science which had its foundations in the work of the great physicist. The lecturer on this occasion, before an audience of eight hundred at the University of Adelaide, was Professor M. L. E. Oliphant who spoke on the problems and possibilities of harnessing the energy released in fusion reactions under the title " Hydrogen Bombs or Thermonuclear Power."

Physical Society Conference on Nuclear Physics

The Physical Society has arranged a conference on nuclear physics to be held at the Cavendish Laboratory, Cambridge, on April 10 and 11 next. Full details and application forms may be obtained from the Secretary of The Physical Society, 1 Lowther Gardens, Prince Consort Road, London, S.W.7. Those wishing to attend should make immediate application to do so.

Symposium on Molecular Structure

A symposium on molecular structure and spectroscopy will be held at the Department of Physics and Astronomy, the Ohio State University, from June 16–20, 1958. There will be discussions of the interpretation of molecular spectroscopic data as well as methods for obtaining such data. In addition, there will be sessions devoted to those phases of spectroscopy of current interest. A dormitory will be available for those who wish to reside on the campus during the meeting. For further information, or for a copy of the program when it becomes available, members should write to Professor R. A. Oetjen, Department of Physics and Astronomy, The Ohio State University, Columbus 10, Ohio.

Mass Spectrometry Conference

The Mass Spectrometry Panel of the Hydrocarbon Research Group of the Institute of Petroleum are holding a conference on Mass Spectrometry at the University of London, Senate House, on Wednesday–Friday, September 24–26, 1958. About 40 papers will be presented on analytical applications, including applications in organic and inorganic chemistry and for solid analysis, instruments and techniques and fundamental problems, by authors from U.S.A., Canada, Germany, France, Holland and Belgium, as well as this country. It is expected the conference fee will be in the region of £4 which will include preprints. Further information may be obtained from W. J. Brown, Scientific Apparatus Department, Metropolitan - Vickers Electrical Co. Ltd., Trafford Park, Manchester, 17.

Vol. 9, March, 1958

The Recruitment and Training of Physicists*

By NORMAN CLARKE, B.Sc., F.Inst.P.

(Deputy Secretary, The Institute of Physics)

IN the past, especially in pre-war days, The Institute of Physics tried to convince industry that it needed to employ physicists, at that time not a widely accepted belief. Through conferences, exhibitions, lectures and publications (this being the origin of the *Physics in Industry* series of monographs) much work was done, but it appeared to bear little fruit. Superficially at least the picture is now different. Advertisements for physicists are prominently displayed and there appear to be many unfilled vacancies. Indeed, the Institute has recently decided—and I applaud the decision—that we must devote far more effort to the stimulation of interest in physics among those likely to be suitable entrants to the profession.

It might be expected that I should assume without question that we need a greatly increased annual output of well trained physicists and of technologists in applied physics. Statistics from the Soviet Union and the United States are commonly quoted in support of this view, especially since the launching of the two Russian satellites, but if I were to deal with the Russian satellites at all my comments would lie entirely outside science; nor do I see much point in bandying figures relating to the production of scientists in any other country. The importance of the maximum production and, equally, the maximum use of scientists by a country in our economic position should have been obvious for long enough, without any suggestion of "keeping up with the Khrushchevs." It is, however, prudent to consider critically the question of numbers and to try to reach a rational policy of recruitment.

It is easy to follow the current fashion and to express profound conviction that every effort must be made to increase, virtually without limit, the output of scientists. This attitude is in marked contrast to the situation in the 1930's, when some of us were graduating. At that time a vacancy for a grammar school teacher of physics would probably produce over a hundred applications from well qualified men, for the very good reason that there were not enough other posts available. Many employers did not know who or what a physicist was, and those who did saw little or no reason to employ him. It would be stupid and wrong to continue to live too closely with the memories of the 1930's, but, when we are now exhorted to produce physicists almost without number, those of us who are anxious that physicists shall have worthwhile and continuing careers are perhaps entitled to look rather critically at the situation as it is, and even to remember how recent is the conversion of some employers.

THE DEMAND FOR SCIENTISTS

Let us ask, firstly, who requires the physicists and, secondly, what they are required for. Alternatively, and more realistically, who is prepared to pay salaries to physicists and for what are these salaries to be paid ? We can dismiss quickly, for this purpose, the undoubted shortage of teachers of physics in schools ; it is largely an accumulated deficit and the number of openings in this field would be comparatively small once the backlog had been made good. The field of employment of vital importance, and at which we need to look carefully, is civil industry. It is a truism that the continuance of our present standard of living critically depends upon the success of civil industry and its ability to apply science and technology, in the face of competition from countries where the value of science may be more widely recognized. Everyone appears to believe this, however reluctant some may be to do anything about it. The recent report of the Advisory Council on Scientific Policy[1] says that for a country such as ourselves "the importance of our effort in scientific research and development can hardly be overestimated." Some of us have become cynical about the contents of White Papers and Government advisory committee reports, but this statement is not in the slightest degree debatable. Yet it is no use producing physicists and other scientists to help our industries to meet foreign competition if major industries that need them are not prepared to employ them ; the same report of the Advisory

*Based on an address to the North Eastern Branch of the Institute on November 7, 1957

Committee comments " we believe that in some industries . . . such as ship-building, building and contracting and some sections of the textile industry, research effort falls considerably short of the best standard in other countries." Whatever may be said by prominent industrialists who serve on Government committees, or by those industrialists who speak on behalf of great organizations like the Federation of British Industries, a continuing resistance to scientific and technical education and to technological change is displayed by many firms. There is certainly from industry as a whole an unsatisfied demand for (young !) scientists but it may be much less than is commonly supposed. Not the whole of industry is crying out for more scientists : some firms are, but the demand is far from evenly spread.

Let us consider, however, the question mark of the Advisory Committee's report that overshadows almost everything else it contains. Who pays our scientists ? More than 60% of all the research (including development) in the country is undertaken in private industry or, at least, industry spends over 60% of all the money spent on research. But industry itself provides the funds for less than 23% of the total research. The great source of money for research, and therefore for paying the salaries of the physicists we have or are to produce, is the taxpayer. No less than fifteen shillings of every pound spent on research comes from the Exchequer ; and of that fifteen shillings about twelve shillings is for defence. Of every pound spent on research by private industry in its own research establishments about twelve shillings comes to it from defence and one shilling from other Government sources. In private industry, the Government employs—or, at least, pays—two out of every three scientists and, officially, they are paid for " defence " work. I am not concerned here with the rightness or wrongness of this from a moral point of view, but unless we are to assume that, for the lifetime of someone graduating at the present time, the foreign policy and the defence programme of successive Governments are likely to remain unchanged, we are faced with a very shaky foundation upon which to plan for any very large expansion of the scientific manpower of this country. If, within the next few years the defence policy were to be changed, because of improved international relations or an economic crisis or for any other reason, we might well have a sudden surplus of physicists. This is a sober fact that ought not to be ignored in a rational appraisal of our position.

It is, however, sometimes argued in rebuttal of this argument that we should increase the number of qualified scientists because they are needed in types of job not at present filled by them. This I believe to be profoundly true, but I am sceptical about the number of openings that, in fact, exist. If industry is backward in employing physicists and other scientists on research and development, from which material results may be expected to flow, it is difficult to believe that there will be rapid conversion to an acceptance of the value of scientific training in management and in other spheres. Again, it is sometimes said that if the research programme for defence were to be curtailed the money thus saved would be available for other kinds of scientific work. Of this, too, I am sceptical. Vast sums of money can be extracted from the Treasury for defence but it is unlikely that taxation could be maintained at its present penal level, nor do I necessarily believe that it would be right to do so, in order to divert money into civilian research channels. We shall not reach a healthy state of affairs until civilian industry is able and willing to absorb, and to use effectively, a greatly increased supply of scientists who can be paid by industry *from its own resources*. There is still plenty of scope for the Institute to continue its work of educating industry to appreciate the scientist.

Bearing in mind that the defence program is likely to continue for some years at a very high cost, perhaps we should aim at increasing the output of physicists by something like 50-70% over the next few years. But it is even more important that we should improve the quality of those who enter the profession, and improve the way in which this scarce and valuable scientific talent is used ; there is a good deal of mis-employment of scientists. It is essential, too, that we provide better training for and an increased output of technicians in industry and elsewhere, for without them professional physicists cannot be most profitably employed.

THE PRESENT POSITION

We then have to address ourselves to two questions. Where are we proposing to recruit the additional entrants to courses in physics, and how we are to train them ? Let us look at the problem quantitatively. In the past virtually all professional physicists have been educated in the universities or in those technical colleges where they have been able to read for external degrees. So we may take the number of degrees awarded as a pretty accurate estimate of the annual output of professional physicists. The report to which I have already referred[1] gives 624 as the number

of honours graduates in physics in 1956, inclusive of the external London graduates. In addition, there were 551 General Science degrees but few of those graduates would be regarded by the Institute as academically qualified physicists. The corresponding figure of honours graduates in physics for the academic year 1938-39 was 151, so we have had a four fold increase. This has not been a steady increase ; since 1952, in fact, the figure has been almost stationary. I have not been able to reconcile the figures quoted by the Advisory Committee with the figures published by the University Grants Committee since the latter presumably exclude the London external degrees ; but if we take the reports of the University Grants Committee and include as honours physics degrees the degrees in mathematics and physics, which would presumably refer mainly to Scotland, and the small number of degrees in mathematical physics or applied physics, we obtain for 1956 a total of 582. The corresponding figure for these degrees for each year since 1948 is :

1948 ...	586	1952 ...	570
1949 ...	519	1953 ...	566
1950 ...	531	1954 ...	585
1951 ...	512	1955 ...	567

In an inquiry that I conducted about three years ago into the availability of places in universities and technical colleges[3] I suggested that about 750 students were admitted each year into the courses for honours degrees in physics or the equivalent, in the universities for which I had information. I am conducting at the moment a further inquiry of the same kind ; it is clear that the intake this year has been substantially greater than that of three years ago.

The report on the earlier inquiry suggested that somewhere around one-third of all those accepted into university honours courses in physics failed to obtain the degree for which they entered the university, and also that there were places for about 25% more students. The first and rather obvious deduction to be drawn is that if the rate of failure could be reduced to that which I think applied before the war we should immediately have our increase of 50% in the output of honours graduate physicists. The rate of failure, in other words either the quality of the intake or the methods employed by universities, would seem to be the first problem to be tackled if we want to obtain more qualified men.

Quality of entrants is a problem which to some extent goes back to the schools and, no doubt, partly arises from the shortage of really good teachers and the large increase in the number of boys in the sixth forms of grammar schools. Before the war probably only the most able boys went on to the university and they were able to spend two or three years in sixth forms with small numbers and with good quality staff to teach them. It would be surprising if the average quality of the intake of the universities had not gone down. This is not a simple problem, however, and it involves much more than the provision of more and better teachers, so often regarded as the obvious and complete solution. The fantastic policy of the Ministry of Education over maintenance grants is undoubtedly one factor ; intentionally or not, this policy puts a severe penalty upon those parents who earn too much to allow them to obtain grants but too little to enable them to maintain their children at the university without real hardship to the standard of living of the family. Many of those parents are professional men, from whose sons it is reasonable to believe that some of the best university entrants might come. This may well be a significant factor depressing the quality of entrants to university science departments. The Government's protestations of concern for scientific effort do not make sense so long as this rule is applied. Another cause of difficulty in the schools is that with the greatly increased numbers in sixth forms there may be greater pressure upon staff to obtain examination successes for their own sake ; whether or not this is so, it is becoming widely believed that the Advanced level General Certificate of Education is rapidly ceasing to have much value as an indication of real knowledge and ability in a subject.

FACTORS INFLUENCING RECRUITMENT

If we are to improve the quality of entry to the universities and if we are thereby to hope for an increased output of good quality physicists, we are bound to try to obtain for physics and for science generally a higher proportion of the best talent in the grammar schools than we are at present receiving. Of course, every profession has the same objective in mind and this is a question upon which the nation has to make up its mind. Ministers of the Crown make speeches professing their concern for an increase in the number of scientists and technologists. They do not make speeches upon the need to have more lawyers, chartered accountants, insurance brokers and members of the Stock Exchange. We are entitled to believe, therefore, that any endeavour we may make to obtain for our own profession more entrants of high quality, at the expense of other occupations, conforms to the national interest and is not a selfish aim. We have to induce boys and

their parents to choose scientific careers rather than other occupations with which perhaps they have a tradition of family connection. We have to seek boys of first-class ability, who may come from homes of a comfortable standard, and we have to persuade those boys that they will not only enjoy their lives as physicists, which I think they would undoubtedly do, but—which is much more doubtful—that they are not committing themselves to lives of lower material standard than their fathers and brothers have obtained or can obtain by careers in business, commerce or other professions.

The Institute has for some years conducted periodical surveys of the salaries paid to its members. These have shown a steady increase in the general level, and the profession now offers a very fair standard of living. But equally, I believe the figures show considerably poorer rewards than could be expected by people of similar intellectual ability in, say, chartered accountancy or the solicitors' branch of the legal profession (professions where private practice is available) or on, say, the sales side of industry. Boys, I hope, will never go into science simply for the money, nor do I hope that they will choose between different scientific openings simply on this ground. But we are being stupid if we pretend that this is not a factor of considerable importance and one that is rightly taken into account by a conscientious parent in trying to advise his son.

Some years ago I was a member of a small committee preparing a report on the education of technicians. It was our practice to invite prominent representatives of industry and the Trades Unions to appear before us as witnesses, and on one occasion we had the managing director of a famous firm of builders. He gave us an interesting account of the importance of craftsmanship and the difficulty of finding boys to learn crafts in the building trade, although he found no shortage of boys wishing to go into his drawing office. I asked him if he would tell us the respective wages of craftsmen and of draughtsmen, whereupon he immediately complained to the chairman that this was an unfair question. The chairman upheld me and the managing director admitted that his draughtsmen had more money, shorter hours, better conditions and considerably more status than did his craftsmen ; yet he professed to wonder why parents persuaded boys to try to acquire the qualifications that would enable them to join the queue for the drawing office. This is very largely a question upon which industry must make up its own mind. If it wishes us to believe that it not only needs but wants more scientists, with the urgency and the sense of national importance that are so often claimed, then industry must show quite clearly that it is willing to pay for what it wishes to have. This involves much more than willingness to join the scramble for new graduates and to pay them very high salaries ; the salaries paid to older men show the kind of future an entrant to the profession can expect, and it is these salaries that are often quite inadequate when contrasted with the rewards of sales managers, accountants or the self-styled " practitioners in advertising." Research is primarily an activity for younger men but scientists do not retire on pension at forty and they are entitled to expect continuing well-paid posts appropriate to their training, abilities and experience. There are, of course, many enlightened firms. One famous industrial concern, which probably employs more scientists than any other, has an excellent record ; more than half its directors are scientifically trained, as are a high proportion of its senior administrators. If this example were more widely followed, the plea for more scientists would evoke a more effective response.

I am not here concerned to plead for better salaries for physicists but I am suggesting that our problem should be seen as the " wants " rather than the " needs " of industry. Industrialists used to be familiar with the workings of a free economy, in which scarcity creates higher prices which in turn tend to increase production. The remedy for the shortage of scientists is very largely in the hands of industry itself ; the Soviet Union has perhaps reached its present scientific strength partly because it understands more clearly than we the validity of some of the principles of classical *laissez-faire* economics that it professes to despise.*

There are other factors militating against an increase in the output of scientists. Among them is often included the real or imagined hostility of some headmasters and other schoolmasters to science. This, in my opinion, is not one of the more serious problems. Probably of more importance is the lack of balance between the number of scholarships awarded in various subjects at Oxford and Cambridge and probably

* In an interesting article in the *Listener* (January 2, 1958), K. A. G. Mendelssohn writes, " While in the West a good physicist will earn five to eight times the unskilled wage, in Russia he will get twenty-five times or more. These tangible attractions, together with the public recognition of his work, provide powerful incentives for the capable young Russian to go in for science, with the result that the State has the pick of the best men in a large population."

at some other universities, where a boy may well have the choice of an open scholarship in classics or no scholarship at all. Again, some parents, not without reason, believe that the results of modern science that are most apparent to them are wholly devilish or, at the best, a strong encouragement towards a materialistic attitude to life. We need to stress the great contributions that science can make to the quality of living, its importance to our national well-being and, not least, its excellence as an education. Greater stress upon these and less upon the destructive power of science might bring us more boys of the kind we desire to have.

The position of girls merits special mention. The present ratio of boys to girls in our universities is about three to two in Arts, three and a half to one in Pure Science and seventy-five to one in Technology. In Pure Science and Technology together the ratio is six to one. Even if one believed that boys made better scientists, this ratio could hardly be justified on the ground of relative intellectual ability. There are many girls of sound intellectual ability, well qualified academically to take up scientific careers, who do not do so ; the attitude of industry towards their employment is often discouraging. I am aware that there are special problems, that the direct training of girls by industry is expensive because the majority of girls go off, as I hope they always will, to get married ; but if industry is not prepared for the greater expense and is not prepared to try to solve some of the problems involved in giving girls a real career suited to their talents, the arguments about the urgency of scientific expansion sound rather hollow. The ratio of boys to girls taking physics as an Advanced level subject is about six to one, but I doubt whether this represents the relative interest of boys and girls in the subject. In 1956, in the Ordinary level General Certificate of Education examinations, 34,000 boys and less than 5,000 girls took physics, 8,000 boys and 4,500 girls took physics-with-chemistry, and 15,700 boys against 10,000 girls took general science. These figures tell a sorry story. The ratio of boys taking physics to those taking general science was more than two to one ; for girls the ratio was less than one to two. In physics, the proportion of passes for both boys and girls was about the same, but the girls did better in general science, much better in physics-with-chemistry and even better still in additional general science. Girls are not given the chance to learn physics. We all know there are difficulties of staff and accommodation. For these and perhaps other reasons there is a far greater tendency in girls' schools to offer the dreadful subject of general science, a hotchpotch of bits of science treated wholly qualitatively and a serious handicap to any child who wishes to study one of the physical sciences with some seriousness beyond the level of the Ordinary Certificate of General Education.

UNIVERSITY EDUCATION

Let us turn to the professional education of physicists, that is to their education beyond school age. At the present time the number of physicists who are educated outside the universities or outside university courses in the major technical colleges is trivial, and for some years it is likely to remain a small proportion. The universities will remain the only important source of supply of physicists, as they will for chemists and for mathematicians. This overwhelmingly important fact appears to have been insufficiently appreciated in recent policy statements about higher education, and in the provision of funds to implement them. Money is now available for technological education on a scale never known before. It is difficult to see why the Government should claim to be anxious to produce more scientists when at the same time it refuses to the universities, the main and only important source of supply of scientists, sufficient funds for the adequate maintenance, let alone the expansion, of the facilities by which alone those scientists can be produced.

We can all make our criticisms of the universities, some of them perhaps substantial criticisms, but we ought to recognize that our profession is singularly fortunate in the quality of the professional education available ; on the whole, our university departments of physics have a remarkable record of success. They owe it, I believe, almost wholly to the fact that in the past they have been able to recruit their staffs from the very cream of the profession. Good physicists are not the products only of teaching or training. They are produced only by other good physicists in the right atmosphere of scholarship and of concern for the advancement of physical knowledge by research. And we should keep well in mind the comment of the Advisory Committee on Scientific Policy[1] ; " Although expenditure on scientific research in the universities represents a relatively small fraction of the nation's total effort, it calls for careful consideration. The universities occupy a position of supreme importance in research. Not only are their postgraduate schools the source of the majority of trained senior research workers in industry and Government establishments, but it is in them that much of the

country's research in pure science is carried out, and it is from their research, directed to the pursuit of scientific knowledge regardless of its applications, that stem most of the major discoveries which subsequently can be applied to industry." In present conditions, when so many other research opportunities are open to able scientists—with good salaries and with better material facilities than the universities can in general provide—the difficulty of the universities in maintaining the quality and numbers of their staffs may stultify all the efforts to increase the output of good physicists. Despite the recent increases in university salaries, I should like to see the status and pay of university scientists substantially increased, both absolutely and in relation to other branches of the profession.

Few of us would wish to make any serious modification of the pattern of the British honours course in physics for a first degree. There is a reasonable variation of emphasis between universities and there is some experimentation. Probably there ought to be a good deal more experiment. In some universities, without touching the present courses, additional courses could be established, perhaps courses in physics and engineering or courses similar to that now successfully run by Professor Lipson at Manchester, with its emphasis upon classical physics and upon experimental ability.

The universities could well give much more thought to the kind of argument put forward by Dr. J. Thomson[4] at an Institute conference last November, urging the presentation of physics as a unified subject and deploring the elevation of mathematics from its place as a tool for the physicist into a replacement of physical thinking. " Physical insight " may be a quality given to the few and one that cannot be implanted, but some idea of its essence can be conveyed. Part of the attribute relates to the ability to create concepts that will link what are apparently unrelated phenomena and that will bring them within the scope of the accepted body of physical theory. The really great experimentalists have been those, I think, who have asked the right questions and conducted the right experiments, and they have done so because they have had a sufficiently clear picture of a possible physical basis of the phenomena they were investigating. And it is the *physical* understanding or ability to formulate a theory or physical model, not mathematical facility, that is vital. The two are often confused. R. S. Silver[5] puts this very well, " . . . theory is never in the mathematics. Some people confuse mathematics with theory. They imagine that, if they cover sheets of paper with successions of mathematical symbols, they are being theoretical, and unfortunately, also other people may imagine that people who write pages of mathematics are being theoretical . . . a theory properly so called must be something which you can put into words. It is, in fact, a statement of assumptions as to what occurs. The mathematical work which follows is not in any sense a development of the theory, i.e. it does not add anything to the theory, it only works out the quantitative implication of the theory. If it appears as if the mathematical treatment has added anything, then it must be found that some other assumptions have been introduced unnoticed, i.e. some other bit of physical thought has been added to the theory without noticing it. It is most important for industrial purposes to stress this aspect of the limitation and of the value of mathematics. One does not get out any more than one puts in—but one does get out the meaning and quantitative significance of what one puts in."

As I see it, the vital quality of the first-rate physicist is that he has something to " put in." How far qualities of this kind can be inculcated or merely developed may be a matter of argument, but a university teacher ought to have as his aim the education of students to the stage where they can display such abilities in some degree. Part of the process of that education must be practice in the asking of questions rather than in the reception of information. The volume of knowledge possessed by a student when he leaves the university is of far less importance than the way he has been trained to use what he does have and the way in which he sets about acquiring more. Some comments of M. Milbourn[6] are relevant, although they were made with particular reference to the inability of graduates to write acceptable English, " Clarity of thought seems to be lacking, as well as clarity of expression, indicating that the course of study has not instilled logical thinking, but has concentrated more on the acquisition of facts and knowledge."

Some university teachers are open to much criticism of the quality of their teaching and of the importance that they attach to it. The place of research in universities can be over-emphasized at the expense of the teaching ; a university has a teaching responsibility that needs to be discharged with the same efficiency and concern as that brought to research. Dr. H. H. Hopkins recently concluded a lecture to the Institute's Education Group by asserting that there were many university teachers who would find that, could they be compelled to listen to their own

lectures, they would not understand them ! A long list of published papers ought not to be the only qualification for a teaching post in a university.

I do not know where it would be right to place the major part of the blame for the 30% failure rate of entrants to physics departments, but at least some of it must lie with the universities. After all, the universities are responsible for the selection of students and if it is subsequently found that the selection was bad or that teaching methods are so inadequate that one entrant out of three fails to obtain the degree for which he was accepted, some drastic action should be taken about either the selection or the teaching.

POSTGRADUATE COURSES

Criticism of the quality of the holders of higher degrees is common and sometimes serious among employers, both in industry and in government service. An Institute report[7] states, " the purpose of the Ph.D. is to provide a training in research," and then adds ingenuously " and the universities should insist upon a measure of originality and resourcefulness in those to whom the degree is awarded." Then follows a masterpiece of understatement, " the standard of originality demanded should, in our opinion, be higher than is sometimes the case at present." Some Ph.D. candidates are regarded more as research assistants than as research trainees, some suffer from inadequate or excessive supervision, some from uninspired selection of problems investigated, more attention sometimes being given to the likelihood of positive results than of the inherent suitability of the investigation as a training. Sir John Cockcroft[8] made the following devastating comment at an Institute conference, " The pre-war unofficial training of the Cavendish School in experimental nuclear physics, in which one had to turn one's hand to glass-blowing or electronics or high vacuum work or magnet-building, did in fact prove to be of first-rate value for the applied physicist, of the war years. On the other hand, we find that in some university research schools the students are working as technicians throughout the whole of their period of study, while in others the techniques and experience acquired are of negative value for later work. In one particular case, the whole practical experience of a Ph.D. student had apparently been limited to passing photographic plates through a domestic mangle to coat them with emulsion. We also find, on interviewing students who have taken a Ph.D., that some of them show an appalling ignorance of elementary physics. A very recent case was that of a physical chemist who had done three or four years' research work and could not even state the second law of thermodynamics or define entropy. This, I suggest is due to lack of formal training and lecturing in the postgraduate years, and it is in marked contrast to the practice of some of the best United States and Continental universities." Since the war the fairly ready availability of funds for the maintenance of research students has meant that the Ph.D. degree has enjoyed an unprecedented boom of popularity, but in the opinion of some the value of the degree is decreasing.

Pre-occupation with research students preparing for the Ph.D. may be a reason why the universities have in general insufficiently responded to the growing need for postgraduate courses of lectures, with perhaps experimental work, leading perhaps to an M.Sc. degree. Such courses could embrace specialized fields of physics, or branches of mathematics commonly needed by the research physicist but not properly included in the undergraduate course. Courses of this kind could also help to relieve the great pressure to add new material to the already crowded three-year course for the first degree. For most physicists going into industry a one-year course of advanced lectures could be invaluable.

TECHNICAL COLLEGES

It is to the technical colleges that many now look in the expectation that a significantly increased stream of engineers and scientists will shortly emerge from them. In the past the principal work of most technical college physics departments or sections has been the servicing of other departments, mainly engineering, the training of technicians through National Certificate schemes and a small volume of more advanced work for the external degrees of the University of London. Very few colleges had courses for the London special physics degree. Usually it was the general degree with physics as one of the three subjects that was attempted, with a handful of students, few of whom got better than a pass general degree, commendable as this was in the difficult conditions of part-time study. Except in rare cases, this degree work has existed only since the war, yet in some colleges the staff seem reluctant to lose it, even in the present atmosphere of technological emphasis and with the ready availability of money for technological courses. With new technological courses such as those for the Diploma in Technology (Dip. Tech.) it is odd to find teachers who still show reluctance to

lose the old type of course and the old attitude of mind, schooled by efficient preparation for external examinations based upon externally imposed syllabuses.

This is not the place to discuss the many difficulties facing the best teachers (and there are some very good physicists indeed) in technical colleges. Improved conditions are emerging in some of the large colleges, especially those recently designated Colleges of Advanced Technology, but many difficulties remain and until they are removed, until more first-class scientists—especially those with research ability—are attracted to the college staffs, it is unlikely that any substantially increased contribution will be made from this source to the ranks of professionally qualified physicists. The successes of technical colleges are all the more remarkable when one considers the handicaps they face and the controls to which they have to submit.* Some colleges suffer from excessive control by the local Director of Education (possibly a specialist on primary or secondary schools) and the whole system is subject to inspection, and often approval, by the Ministry. There can be few fields where freedom is more important than in education ; if we want more first-class men in technical institutions in order that they may educate an increasing number of able scientists, the Minister of Education must accept this truth.

The Dip. Tech. has in general been welcomed by technical colleges but it is much too early to expect that any substantial number of professional scientists will emerge by this route.

The supply of students is sometimes difficult, although there are sings that this may be overcome. For various reasons, including the policy of the Ministry of Education on maintenance grants and means tests, industry is recruiting some exceptionally able apprentices from public and grammar schools, many of them with two or three Advanced level science subjects. Some of the more progressive firms have enthusiastically supported sandwich Dip. Tech. courses and have supplied students of this quality. But this method of training is expensive and if students receive wages during college periods—as many do—considerable expense falls directly on industry. Many small firms feel that they cannot afford the system.

A major problem is college facilities, especially staff. The Government is providing £70 million for new buildings and equipment. This will provide some of the much needed accommodation and modern equipment, but without adequate staff we shall get nowhere in the production of first-class physicists — and the Dip. Tech. is doomed from the start if it is immediately the label of those lower than the best. I am one of those who is very anxious that the Dip. Tech. courses should succeed, that the opportunity should be taken to create technological institutions that are comparable in quality and freedom with the universities but are doing work that is different from university work. Despite the improved status of the new Colleges of Advanced Technology—still, however, subject to Ministry inspection and control—the Ministry has, I think, refused to face some of the problems of attracting first-class staff into the few really major technical institutions. For a successful Dip. Tech. scheme with internal examinations and classifications, the head of department and his staff need to be comparable to university staffs and to be able to create, through the development of research, a comparable atmosphere. I have visited most of the larger technical colleges in Great Britain and in my view there are barely a dozen colleges with facilities in physics remotely sufficient to enable them to provide an adequate course for a Dip. Tech. in physics. Within the next five years or so the annual output of fully trained physicists from Dip. Tech. courses is not likely to exceed 50—if the standard is to be genuinely comparable with that of an honours degree, as I believe it will be.

Some of the schemes that I have seen are excellent, but in some of the others (including several rejected by the National Council) there is too much reliance upon lecturing students into diplomas—25 or more hours a week, probably 15 of them lectures and some supervision for perhaps five of the remaining hours.

CONCLUSION

To summarize, an increase in the available number of scientists will result only if the several professedly interested parties are prepared to display more realism, more action and less oratorical fervour. Industry still needs to show that it is prepared to employ more scientists—especially when they pass the age of thirty-five—and to offer them rewards at least as great as those given to categories of employees not normally regarded as urgently needed. The Government still needs to appreciate that the universities ought not to

* See, for example, the article " Too Many Masters " by Prof. M. R. Gavin in the April, 1956, *Bulletin* (p. 93).
Ten years ago, in *The Education and Training of Technologists* (now out of print), the Institute urged that a limited number of Colleges of Technology should be given " an autonomy equal to that of the universities."

be starved of funds and that adequate status and payment of university staffs are vital factors in any serious plan to improve the output of scientists. The Government also needs a courageous policy for technical colleges, recognizing that we have adequate teachers for only a small number of colleges that can attempt work of the highest level. And all of us who try to serve science need to assert more firmly that our subject is a worthy intellectual discipline, with potential applications that can greatly enhance the quality of life, rather than a technique for the development and military protection of a materialistic society that many of us find increasingly distasteful.

REFERENCES

1. *Tenth Annual Report of the Advisory Council on Scientific Policy* (1956-57). H.M. Stationery Office (1957).
2. *Returns from Universities and University Colleges in receipt of Treasury Grant.* H.M. Stationery Office.
3. *The Availability of Places for Physics Students in Universities and Technical Colleges.* The Institute of Physics (1955).
4. *The Education of Physicists in Universities and Technical Colleges.* The Institute of Physics (1957), p.11.
   See also J. Thomson. *Bulletin of the Insittute of Physics* **5** (1954), p. 37.
5. R. S. Silver. *British Journal of Applied Physics* **2** (1951), p. 241.
6. M. Milbourn. *Bulletin of the Institute of Physics* **8** (1957), p. 229.
7. *Problems concerning the Education of Physicists.* The Institute of Physics (1953).
8. *The Education of Physicists in Universities and Technical Colleges*, p. 4.

Meetings of the British Nuclear Energy Conference

Constituent Societies :
THE INSTITUTION OF CIVIL ENGINEERS, THE INSTITUTION OF MECHANICAL ENGINEERS, THE INSTITUTION OF ELECTRICAL ENGINEERS, THE INSTITUTE OF PHYSICS AND THE INSTITUTION OF CHEMICAL ENGINEERS

Members of the Institute are invited to attend the following meetings.

April 16 5.30 p.m.

At The Institution of Electrical Engineers

" Operational Experience — Calder Hall "

K. L. STRETCH

(Tickets are not required)

May 1 At Church House, Westminster, S.W.1 2.30 p.m.

Sponsored by The Institute of Metals

Symposium on

" Plutonium and methods of handling it "

Papers to be presented are as follows :

" A history of the early British work on plutonium metallurgy "
PROFESSOR J. G. BALL and W. B. H. LORD

" Some facilities for the study of plutonium and its alloys "
G. K. WILLIAMSON, D. M. POOLE and J. A. C. MARPLES

" Techniques for the study of plutonium metal "
W. B. H. LORD and M. B. WALDRON

" The plutonium-iron system "
P. G. MARDON, H. R. HAINES, J. H. PEARCE and M. B. WALDRON

" A preliminary investigation of the plutonium-thorium system "
D. M. POOLE, G. K. WILLIAMSON and J. A. C. MARPLES

" Some investigations on plutonium metal "
E. DEMPSEY and A. E. KAY

All six papers will be printed in *The Journal of the Institute of Metals* before the date of the symposium.
(Tickets are not required)

The Physicist in the Industrial Group of the U.K. Atomic Energy Authority

By L. ROTHERHAM, M.Sc., F.I.M., F.Inst.P., and T. EDGE, B.Sc.Tech., A.I.M.

(*Industrial Group, U.K. Atomic Energy Authority, Warrington, Lancs.*)

INTRODUCTION

ONLY some twenty years ago, some people felt that physicists seemed to be turning their backs on the larger opportunities in the industrial world and entering a sort of cul-de-sac. If they had been studying chemistry, engineering or metallurgy, a place in industry was assured for them, but, as physicists, the only outlet, other than the possibility of academic research, appeared to be in training others to become physicists. At that time, physicists were employed in the radio and communications fields and some were carrying out physical researches of the classical type in universities and the research laboratories of the largest industries. Enlightened managements were even then using a few physicists to work closely with their engineers, chemists and metallurgists, but usually had no very clear idea what they expected to gain from these alliances.

During and since the war this situation has radically altered. Even in the radio and communications fields, the work of the physicist has been rapidly expended. The advent of nuclear fission, its exploitation for the production of weapons and the ever widening area of peaceful uses has, however, provided a great new field for the physicist working independently or in close collaboration with the other sciences and technologists. In this country, the Atomic Energy Authority has its Research Establishment at Harwell and its Weapons Centre at Aldermaston where theoretical physics, nuclear physics or reactor physics are large enough activities to be organized as separate departments or Divisions. The Authority also undertakes production of fissile material which involves building and operating piles, diffusion plants and associated chemical and metallurgical plants for the manufacture of fuel elements and recovery of the fissile material. In addition, it is responsible for the building of prototype power producing reactors on which the country's future electricity generating program depends. These functions of the Industry are carried out by the Industrial Group of the Atomic Energy Authority with its Headquarters at Risley and its factories at Springfields, Windscale, Calder Hall, Chapel Cross, Capenhurst and Dounreay. There are large laboratories of the Industrial Group's own Research and Development Branch at all these locations and also a metallurgical laboratory at Culcheth near Risley. It is the work of the physicist within this Industrial Group organization that we wish to outline in this paper. It may be thought that this is an unnecessarily restrictive treatment, but the work of physicists in atomic energy includes the whole field of physical science and if a short paper is to be more than a catalogue of their activities some slight restriction of the field for discussion is necessary. Within the Industrial Group alone, physicists have their place at all levels from the individual research worker to managers of factories, directors of Research and Development Establishments, or as planning personnel engaged in the formation of technical policy. The Group has its share of physicists working independently of the other sciences, as at Harwell, but in smaller numbers appropriate to the needs of our organization, and the most interesting feature is the way in which, in our organization, the physicist has been integrated into the work of the other sciences and technologies.

In earlier years and other industries the metallurgist, chemist or engineer, needed assistance from the physicist, but perhaps would be reluctant to admit it so that progress was largely based on previous experience and was made chiefly by processes of trial and error. In building up the atomic energy industry, where little previous experience was available in wide areas of technology essential to the rapid development of the new industry, the methods of the physicist and mathematician were indispensable. Experimental work to provide fundamental data could be carried

out by chemists, metallurgists or engineers and, of course, physicists, but the interpretation, extension and application of experimental results to an expanding industry depended more and more on the physicist's approach. We find, therefore, within the Industrial Group, the physicists' technique applied in most of the significant metallurgical, chemical and engineering developments and applications of these developments to an extent beyond anything which would have been possible without these techniques.

The Industrial Group was first engaged in the building of reactors with associated chemical plants to provide fuel elements and re-cycle the irradiated materials after extracting the plutonium for use and the highly active fission products for storage and disposal. Later, a diffusion plant was built, and, more recently, the function of the Group has been extended to include the building of prototype power stations and experimental reactors. Let us now consider a few illustrations of the physicists' work in each of these phases of the Industrial Group's program.

REACTORS

Before the atomic energy industry in this country was called upon to design reactors, a considerable amount of preliminary experimentation had already taken place in America and Canada and although we had only limited knowledge of the later extension of this work to the building of the American production facilities, we had a reasonable amount of data available to help us construct the first piles. The first step, of course, is to do some preliminary calculations combining physics with engineering, economic and other considerations and form a rough idea of the type and size of reactor which is likely to meet the requirements. Assuming that this task has been satisfactorily carried out, the first step for the physicist is to provide information for the design of the core. The principal parameters to be optimized are the dimensions of the fuel elements and the pitch of the lattice which they will occupy in the moderator. Preliminary calculations are made, based upon the nuclear data for the atomic nuclei in all the core materials. For this purpose the physicist will require to know the fission, absorption and scattering cross sections of these nuclei and, if they are not already published, he will have to set up experiments to provide them. He will also need to know the number of neutrons which will be emitted by a fissile nucleus per neutron absorbed and, of course, most of this data is already available for neutrons of thermal energies. In the design of a fast reactor where the data must be related to fast neutrons the available information is incomplete and experimental work to provide the data is still required. Preliminary calculations are intended to provide approximate parameters and indicate the range likely to be of interest for the next stage of the work which is experimental. Small scale critical assemblies and exponential experiments operating at zero energy are the principal tools in this phase of the design which is a determination of the general nuclear characteristics of the system. In the past, most of this type of work was undertaken at Harwell but, as the main interest at Harwell is in longer term research, the Industrial Group is now doing a good deal of the work for the reactors which they are currently building. In the earlier stages of design calculations a simple cylindrical solid bar might be assumed for a fuel element but, later, equivalent hollow tubes or combinations of flat plates may be developed as an optimum solution to the joint demands of physicist, engineer and metallurgist. Each change in philosophy of design for any single component must be reflected in corresponding movements in the other parameters and involves repetition of calculations and re-orientation of experimental work in other fields so that the physicist must work closely with all who are contributing to the design. Gradually a design emerges and a reactor is constructed but the physicist's work is not yet over. Even the start-up operations must be conducted as a large experiment in the manner of the earlier criticality and exponential work. Physicists plan the loading sequence and are present to observe or to take measurements of all significant events or changes in quantities such as flux, temperature, or power level as loading proceeds to criticality. The information is compared with the theoretical calculations and, where necessary, procedures and plans are revised so that, as the pile is brought to full power, the optimum operating conditions are achieved. An interesting aspect of the start-up work is that the reactor may be the largest and most appropriate research tool to become available to the industry and, by careful planning of the charging sequence, information on criticality and nuclear data may be obtained with an accuracy surpassing that resulting from smaller scale laboratory work, and the checks on calculations may result in more sophisticated mathematical techniques being developed for the future. With so many possible sources of error it may be that the actual results differ from those calculated for a variety of causes. On one occasion heat-transfer data may be at fault, on another some item of nuclear data or an impurity level in one

of the components of the core may be greater than expected. Whatever the cause, some variation from the predicted behaviour is certain to arise and only by studying the behaviour of the operating reactor will it be possible to devise means for reducing the margin of error in the future.

Physicists must, therefore, take their place in controlling the operation of a given reactor and feeding back data for future use. Initially a reactor may be fuelled with one type of fuel element and in the simplest case the flux distribution radially is a Bessel function and axially is of sinusoidal form with a maximum value at the centre and minimum values at the ends of channels and at the circumference. In normal operation it will usually be desirable to modify the natural flux distribution by introducing limited quantities of absorbing material in the centre zones to reduce the peak value slightly and extend towards the circumference the zone in which this reduced value operates. This process of " flattening " results in a larger amount of fuel being irradiated to a uniform and moderate value while none is subjected to excessively high doses. To be able to control and maintain a flux distribution of this type implies some method of flux measurement, and flux plots by measuring the residual activity of wires or foils after irradiation in selected positions in the pile are regularly maintained. In time the reactivity of the fuel changes because of the build up of fission products with different nuclear characteristics from the original fuel and because of the production of new fissile material such as plutonium in a uranium fuel. These changes must be followed and compensation made in some way, which may range from replacing part of the fuel to making adjustments in the original distribution of control rods and other absorbing materials. A given reactor may have a life of twenty years or more and during this time re-assessments of the original concepts must necessarily occur. As a result, new types of fuel element may be introduced and the core of a reactor may ultimately contain several types of fuel element of different materials and dimensions, provided these differences can be accommodated within the scope of the original design. Similarly there may be differences in the nature of the absorbing materials responsible for the flux pattern. In the earlier days these may be wasteful materials such as steel, but at a later date the material may be selected to yield a useful product after irradiation. In working out the operating schedule the physicist must obviously play a major role, but generally he will have to take into account economics and a wide variety of allied considerations which will broaden his viewpoint and help towards his progress in management functions.

Another factor in the successful operation of reactors is the possibility of failure of fuel elements. Essentially these are pieces of fuel enclosed in a suitable form of container which serves the dual purpose of protecting the fuel from chemical interaction with its coolant or moderator and providing an extended surface for optimum heat-transfer properties. Failure implies rupture of the container followed by chemical interaction with the environment. Usually this would result in the rapid formation of a large amount of uranium oxide which might spread within the pile and associated plant, taking with it the most highly active and dangerous fission products. Some of the fission products, as for example, krypton and xenon, are gaseous and in the event of rupture of a fuel element they may be sampled in the gaseous coolant stream so that when they decay to form solid daughter products these may be separated by electrostatic precipitation and monitored to provide an indication of the burst fuel element or cartridge. The design of equipment for the detection of bursts is an essential feature in the construction of reactors and one in which the physicist plays a prominent part.

The effect of irradiation on most of the materials in the core presents most intricate problems in solid state physics and metallurgy. In a graphite moderated pile, for instance, continued neutron bombardment results in displacement of graphite atoms to interstitial positions and if the moderator is working at low temperatures below about 200°C these atoms do not all return to their normal positions in the lattice. The result is a storage of energy which eventually builds up some degree of instability so that the displaced atoms tend spontaneously to revert to equilibrium positions with evolution of heat. This process of storage of energy must be followed carefully by the physicist and steps must be taken to ensure that a dangerous release of this energy does not occur. Graphite studies therefore form a large part of the work of our solid-state physicists. Samples of graphite are placed in selected positions in every graphite moderated reactor and a few of them are withdrawn from time to time for measurement of all relevant physical properties. Calorimetric work provides a measure of stored energy and gives an indication of the conditions necessary for its release, while dimensions, density and mechanical properties can be checked to provide a basis for predicting gross changes in the condition of the moderator.

The fuel elements also suffer irradiation damage but the temperature of the fuel is invariably higher than that of the moderator and while the annealing process is more rapid the damage mechanism is more complex. Fission products cause a decrease in density even when they are solid elements and the temperature is low but at temperatures much above 300°C the creep strength of metallic fuels is low enough for gaseous fission products to cause large decreases in density sufficient to result in swelling of the fuel unless mechanical restraint is applied. At temperatures below about 300°C the orthorhombic structure of uranium and its different coefficients of expansion in the principal crystallographic directions combined with its different mechanical properties in compression and tension lead to growth of fuel elements which in its commonest form is found as a wrinkling of the surface of cast or randomly oriented material. The metallurgist is much concerned with the study of these phenomena and the mechanical properties, particularly creep, under irradiation. The physicist however is called in to study with the metallurgist the diffusion of the fission product gases in fuels at high temperatures or to devise methods for measuring extensions in creep under irradiation, not to mention the design of in-pile rigs for maintaining specimens of fissle materials at constant temperatures for creep testing. The diffusion studies involve refined vacuum annealing techniques or purging with extremely pure argon to evolve krypton or xenon from radioactive specimens. All the operations must be carried out by remote control behind protective shielding and the determination of the gases is by radiochemical techniques. In-pile rigs for creep testing may involve stressing a specimen at uniform temperature at the bottom of a 4-inch diameter tube over 30 feet long inserted through the concrete biological shield and projecting into the core of a reactor. Considerable temperature gradients will exist in the tube and there can be no question of an optical extensometer being placed at the bottom and observed at the top under these circumstances. The physicist is therefore called upon to devise a reliable means of measuring small extensions and moreover a method which will be suitable for use under high neutron fluxes in the core of a reactor. Designing rigs for use in-pile even for the apparently simple purpose of maintaining a few small samples of fissile material at a uniform temperature is by no means a simple operation. The small sample itself evolves heat which may be more or less than the amount required to maintain it at the required temperature while the pile is operating. Supplementary heating elements must be combined with a cooling system in such a manner that if the pile is shut down the loss of heat from the specimen itself is small in comparison to the externally applied heat while the cooling system is adequate to prevent undue rise of temperature in the pile close to the test rig. The design of a rig or an experiment with unusual specimens in an otherwise uniform core involves almost as much work as the design of a core itself and is a very important field for the theoretical and experimental physicist.

CHEMICAL PLANTS

After irradiation the fuel elements are dissolved and treated chemically for the extraction of plutonium, the separation of fission products and the re-cycling of uranium. The main problem is radioactivity which requires all operations to be carried out behind massive concrete shielding until the principal gamma active components have been stripped from the solutions and removed to shielded storage areas. Thereafter the alpha active and beta active materials are handled more readily behind transparent plastic screens in specially designed cabinets. Shielding problems are nowadays well understood but nevertheless they are an important field for the physicist working closely with the design engineer to ensure that an adequate but not extravagant allowance is made. A secondary problem but one which overshadows the shielding problem because of its complexity is criticality. It is necessary at all times to ensure that a chemical plant cannot contain sufficient fissile material in the right geometry for a critical mass to assemble. This gives rise to the concept of the " Eversafe " vessel which is usually so long and narrow as to violate all principles of experience and common sense in chemical engineering. Such vessels, it is calculated, could not contain sufficient material under any conceivable circumstances to produce a criticality hazard. It is easy enough to design vessels based on the most pessimistic assumption and the simplest theory, but when the designs are not realistic the need for a proper study of criticality in chemical plant becomes obvious and this again is the province of physicists at our Dounreay Establishment where an elaborate criticality facility has been constructed. Here, additions of fissile material can be made to a near critical assembly under control from a remote station 300 yards away and under continuous observation by closed circuit T.V. The results cannot fail to improve the approach to design problems and eventually should lead to plants

which are not only safe but good engineering designs based on a sound theoretical knowledge.

FUEL ELEMENTS

Many of the problems of fuel elements have already been covered under the heading of Reactors but since the performance of a reactor is so dependent on its fuel elements some aspects of fuel elements deserve further mention. The development of satisfactory heat transfer surfaces for in-pile service is a borderline area for the engineer and physicist and much of the work is properly that of the physicist. At lower heat fluxes extended surfaces in the form of fins have advantages and the development of the appropriate form of fin in a given case requires large models of fins in a variety of sizes at varying angles to the coolant flow and with facilities for blowing gaseous coolants or pumping liquid coolants through these models while observing pressure drops, flow characteristics whether laminar or turbulent, and the efficiency of various designs in removing heat from a given heat source. Experiments of this type may show that, in a given case, a longitudinal arrangement of fins is most effective by comparison with a radial or circumferential design from the point of view of maximum heat transfer with minimum pumping power. The physicist however may find the circumferential design is lighter and offers less competition to the fuel in the neutron economy of the pile. The possibility of using a fuel enriched to some extent in U^{235} may then have to be considered. If there is an adequate supply of this or other suitable fissile material available the cost of processing it and incorporating it in fuel elements to restore the neutron economy will have to be weighed against the cost of providing increased pumping power. If there is not an adequate supply of additional fissile material the choice for the time being may well favour the lighter weight, less efficient transverse finning, but will emphasize the need for provision of suitable fuels in the future so that advantage may be taken of the more efficient forms of heat-transfer surface. In thermal reactors without enrichment the only materials which may be tolerated in the core as fuel element containers are those with low competitive absorption and as most of these are lighter elements such as aluminium, magnesium or beryllium with low melting points or low strength at higher temperatures the operating temperatures of such reactors may be seriously limited. With fast neutrons, however, the competitive absorption factor is much less important as even the heavier metals have relatively small capture cross sections for fast neutrons. Steels or materials like niobium may be used in such cases and the operating temperature of the reactor may be considerably higher in consequence. In these cases the fuel will be highly enriched and the balancing of engineering and physicists' considerations suggests thin plates or tubes which even so will exhibit very high temperature gradients. At very high temperature gradients and heat fluxes finned heat transfer surfaces are no longer required or at most only small ribs may be raised on the surface of fuel element containers. Here again large scale models of tubular fuel elements have been studied in flowing coolants of various types to provide the optimum design.

DIFFUSION PLANTS AND SEPARATION OF ISOTOPES

Diffusion plants are just as important a sphere for the physicist as are reactors, but owing to their military significance are not topics which can be discussed in any detail at the present time. Everyone knows however that the purpose is to produce uranium containing a greater proportion of the U^{235} isotope than the natural isotopic mixture contains. The method is to pass the natural mixture in gaseous form through a fine membrane and, since the lighter isotope diffuses more rapidly than the heavier, collect two fractions of gas, one enriched in the lighter isotope and one depleted. If a large number of membranes is assembled in a diffusion plant the enriched fraction passed by the first membrane may be further enriched by repeating the operation in other stages "up the line" while the depleted material from each stage is sent down the plant to be further depleted. Ultimately if such a process is carried to a sufficient number of stages a small quantity of pure U^{235} will be obtained at one end of the plant and a large quantity of U^{238} will come out at the other. In the design of this type of plant the physicist is much concerned with working out the optimum course for the gas to follow as there are numerous ways of arranging the re-cycling process and some of them are less costly capital projects while others are cheaper to run. Studies on the efficiencies of membranes and on the thermodynamics associated with circulating the gas in the plant together with ensuring that patterns of gas flow are satisfactory are only part of the physicists work. Some parts of the process are carried out at reduced pressure and a plant with several hundred miles of pipework and vessels is in practice so vacuum tight that if the vacuum pumps were shut down, and valves closed to isolate it, many years would pass before the interior returned to atmospheric

pressure. To achieve this, remarkable advances in vacuum technology have been required and the physicist has naturally been in the front line at all times. Instrumentation, leak detection, cold trapping and studies of reaction rates between the gases and the materials of the plants are all large fields of study in which the physicist has been prominent. Other methods of isotope separation exist and in the past centrifuges have been studied widely. For materials other than uranium, boron for example, low temperature distillation processes are available. The material in liquid or gaseous form as a chemical compound is submitted to fractional distillation and the required isotope concentrated in one of the fractions. The physical properties of the chemical compounds, in cases like this, may only have been investigated at normal temperatures and the problem for the physicist is to investigate thermal conductivities, viscosities and densities for his chemist colleagues but carrying his studies into the low temperature and high vacuum regions. Mass spectrometry is a field of special interest in this business of separation of isotopes and our physicists are always engaged in improving methods and equipment to provide adequate means for the detection and estimation of new materials.

CONCLUSION

In this brief paper we hope we have been able to convey to you something of the breadth and interest which the physicist may encounter in the Industrial Group of the Atomic Energy Authority in the course of his normal work.

We have not attempted to cover all the work done by physicists in our laboratories, but tried to show that the interests of most people can be met in one laboratory or another. No one in our work need feel that his scientific interests will be restricted, although the Industrial Group Research and Development Branch is essentially an applied research organization. To many of us this indeed is an added attraction since we can also feel that we are making an early contribution to the well-being of the whole organization and thereby to the national economy.

Correspondence

Newton's Conception of Scientific Method

I have read with interest the article by A. C. Crombie on Newton's Conception of Scientific Method.

In view of Mr. Crombie's undisputable assertion that " the problem for the historian is to distinguish an interpretation of the intentions and conceptions of the past from an evaluation of them in his own terms, and to avoid making an unconscious selection which distorts or simply eliminates genuine aspects of the thought of a scientist . . . because they are not acceptable or interesting in the modern context or to the historian personally,"[1] it is difficult to understand why Mr. Crombie summarizes the views of Auguste Comte on science as follows : " In Comte's view—and Mill certainly agreed with it—the real object of science had always been ' savoir pour prévoir,' prediction to give control."[2] Having thus interpreted Comte's views Mr. Crombie suggests that a revealing indication of the origin of Comte's " savoir pour prévoir " can be found in a passage from Descartes' *Principia Philosophiae* which he quotes at length.[3]

Surely the correct translation of " savoir pour prévoir " should be " to know so as to foresee." By distorting the translation to " prediction to give control " and claiming that in Comte's view this was the real object of science the false impression is created that Comte in his positivism had anticipated the often heard modern conception (or misconception) that the real object of science is to control nature. Such a conception would have been quite unacceptable to Comte.

It would also be very interesting to know what is the actual origin of the epigram " savoir pour prévoir " so often attributed to Comte. Although Comte often expressed similar ideas,[4] I suspect that this particular epigram is Mill's own.[5]

A. Tarnowski (*Associate*)
Rochester, New York, U.S.A.

REFERENCES

1. *Bulletin* of The Institute of Physics, **8**, 351 (1957).
2. *Ibid.*, 350.
3. *Ibid.*, 357
4. e.g. Auguste Comte. *Cours de Philosophie Positive*, **2**, 20, or **3**, 195. Paris (1869).
5. J. S. Mill. *Auguste Comte and Positivism*, 6. London (1865).

m.k.s.A. Units and the Teaching of Electricity

At the risk of prolonging the series of interesting articles which have appeared under titles similar to the above, may we make a point and ask a question ?

The former concerns the way in which the m.k.s.A. system of units has become entangled with the teaching approach based on Ampèrian electrodynamics. There is no reason why the approach based on the magnetic pole should not be used with the m.k.s.A system. In fact there are available elementary textbooks, e.g. Fowler,[1] which do just this. The two teaching methods are compared in the excellent articles generally known as "The Coulomb's Law Committee Report,"[2] where the various forms the equations take in several unit systems are set out.

The question refers to the famous "fourth experiment" of Ampère, from which the dependence with distance of the force between currents may be deduced. In his Memoire, Ampère states, in the last paragraph of the last page, that he has not had time to construct the apparatus and that the experiment would, anyway, only confirm results obtained otherwise (the extract on page 45 of Dr. Tricker's little book[3] may be more readily available than the Memoire). It would be interesting to learn whether Ampère, after 1825, did construct and use the equipment he described. Ampère's argument for the inverse powers in his formula, which is not based on this particular experiment, is long and involved. The use of his "result" for the fourth experiment is much preferable, at least in elementary courses.

K. E. Grew (*Fellow*)
F. C. Flack

University of Exeter

REFERENCES

1. Fowler, R. G. *Introduction to Electrical Theory.* Addison-Wesley, Cambridge, Mass. (1955).
2. Coulomb's Law Committee. The Teaching of Electricity and Magnetism at the college level. Parts I and II. *Am. J. Phys.*, **18**, 1 and 69 (1950).
3. Tricker, R. A. R. *On the Teaching of Electricity in Schools.* John Murray (London: for the Science Masters' Association) (1955).

It would indeed seem doubtful whether Ampère ever performed his "fourth" experiment, and I regret that in my article in the December *Bulletin* (p. 389), it was stated to have been carried out. Yet, as Dr. Tricker states, there can be no doubt that the inverse square law does hold for the force between two current elements. If a rigid proof is required for elementary courses, it would indeed be simpler to be able to quote the result of a single direct experiment such as Ampère's "fourth" !

E. O. Hercus (*Fellow*)

University of Melbourne.

Physics among the Sciences

Sir Cyril Hinshelwood, in his article on Physics among the Sciences in the September issue of the *Bulletin*, appears to make unnecessarily heavy weather in his references to the mind-matter relationship. Discussing vision, he writes, "... the physicist falls into error if he makes a facile identification of the brain process with the experience of seeing," and then purports to disprove this association by describing eloquently the case of a man born blind who knows all about light waves and their frequencies, nerve processes, patterns of cortical activity, etc., but still does not have the experience, say, that a normally endowed man looking at a red rose has. This example, however, really has no relevance to the point at issue, since one can safely assume that the physiological brain processes involved in thinking about frequencies, cortical activity, etc., are different from those involved in looking at an object.

It would seem that only confusions of this sort could lead to describing the mind-matter relationship as one of "disturbing discontinuity." Is it not merely the case that seeing is a way of behaving of people and animals, just as the propagation of light waves is a way of behaviour of space or the transmission of electrical signals is a way of behaviour of nerves ? The discontinuity between the third and first of these is no more—or, at any rate no less !—disturbing than the discontinuity between the second and the third.

B. Meltzer (*Fellow*).

University of Edinburgh.

Increasing the entry to the profession

It is only natural that when, as an Institute, we wish to stimulate entry to the profession we think first in terms of committees, organized exhibitions, lectures, etc. All this is necessary ; but is it sufficient ? Is it making sufficient use of the opportunities open to our members at large ?

When Mrs. A tells Mrs. B, her neighbour, that she has had remarkable results with "Zetawite" there is a reasonable chance that Mrs. B. will switch to this—I hope—imaginary detergent. It is the dream of every organizer and salesman that neighbour will "talk it up" to neighbour.

If we contemplate the abysmal ignorance, in general, of our neighbours on the subject of the physics profession, does it not become our neighbourly duty to assist them when their children are in need of help ? Despite the traditional reticence of scientists there is probably something to be gained by offering to take a small group of neighbouring children to the Science Museum, or to our own laboratories. Handing a copy of *Physics as a Career* to a worried parent should be less embarrassing than extolling " Zetawite." There must be many such gambits which each and every physicist could employ with hardly any effort. Perhaps this letter will stimulate suggestions and individual action.

There remains, however, one disturbing consideration. In waging an organized and a " disorganized " campaign to stimulate entry into the profession, are we not making unverified assumptions as to the major influences which, in fact, stimulate a boy or girl to take physics ? Each of us can presumably give a reasonably coherent explanation of why we, as individuals, entered the profession. But until we know which are the typical and which the exceptional reasons, our present efforts might be directed uneconomically. Perhaps the Institute could usefully conduct a survey aimed at establishing the reasons which stimulated its members to become physicists.

G. C. Eltenton (*Fellow*).

11 Queensbury Avenue,
Bromborough, Wirral,
Cheshire.

Reviews of Books

TELECOMMUNICATIONS — An introductory Textbook for Engineering Students

By W. Fraser

London : Macdonald and Co. (Publishers) Ltd. Pp. xii + 772. Price 65s.

In his preface, the author claims that this book covers the subject for the University of London Engineering degree, is suitable for the Higher National Certificate and is also useful in preparation for the " examinations in Radio and Line Communications of the Institution of Electrical Engineers, and for the higher grades of examination in telecommunication principles held by the City and Guilds of London Institute."

This claim is certainly justified ; indeed, it is difficult to find any aspect of the subject which is not only discussed thoroughly at the appropriate level but where, furthermore, worked examples and well-considered references are not given. In addition, many examples from university degree and Institution of Electrical Engineers' examinations are collected at the ends of the chapters. The book contains such a wealth of information that any lecture course in telecommunications would have to select from the material given. There is, however, undoubtedly a demand for such comprehensive texts ; they are invaluable to the student as companions for reference during his courses and, in general, the good student finds a book more useful which gives a full discussion of difficulties he may encounter in lectures rather than a work which covers the bare essentials.

The first six chapters are concerned with networks, resonant circuits, coupled circuits, transmission lines, attenuators and filters. To appreciate the rather sudden introduction of such topics as Rosen's theorem and Thévenin's theorem, the reader would need to understand well his basic electricity and magnetism, but this urgency to lay a satisfactory foundation of analysis for the subsequent understanding of electronic circuits is, on the whole, to be preferred in a book of this kind.

Thermionic vacuum tubes, transistors, amplifiers, oscillators and power supplies are dealt with in chapters seven to twelve inclusive. Though a thorough treatment, there are some minor criticisms. On page 203, the reader is left with the idea that a thermionic valve is evacuated to prevent oxidation of the emitting surface ; the more important concept of the increased mean free path of electrons as the pressure is lowered is not mentioned. The description of the action of the grid in a triode valve (page 205) could be improved with advantage. Occasionally, the writing is not sufficiently precise : for example " if the grid is made sufficiently negative . . . the anode is then said to be ' cut-off ' " (page 206), and " the presence of the load resistance R causes a voltage to drop " (page 212). In the account given of transistors, the very short section " Electrical Conduction in Solid Materials " could be extended with advantage. Otherwise, the engineering student will find it difficult to appreciate satisfactorily such statements as " If,

in a semi-conductor, an impurity material is present which fits into the regular crystal pattern except that it has one more electron in the outermost orbit compared with the semi-conductor, then the excess electron will move through the crystal lattice and act as a current carrier" (page 235).

The remainder of the book (ten chapters) is concerned with accounts of the basic theory and practice of the circuits and apparatus associated with telegraphy and telephony, including picture telegraphy and television. The presentation is well thought-out and includes good accounts, with the relevant mathematics, of the fundamentals associated with practice at audio, video, high and ultra-high frequencies.

Six appendices are included. The first one "Mathematical Formulae" might well have been omitted. The equations gathered together are in a great many texts and, surely, a student able to read this work does not require, for example, a half-page account of differentiation. Appendices E and F are concerned with electromagnetic theory and are a necessary background to a good understanding of data in the main text on such topics as transmission lines, wave-guides and aerials. These two appendices are, however, too brief to expect an understanding from the student unfamiliar with the Maxwell concepts; it would possibly have been preferable to include these data earlier.

The book is well printed and illustrated except that some of the photographs would be clearer if printed on specially inserted paper. The volume is too thick: if it is as well-used by the student as it deserves to be, it will surely come apart in due course. Despite the 772 pages, the use of thinner paper and a larger page would have resulted in a handier book.

J. YARWOOD.

THE ELEMENTS OF PHYSICS

By A. W. Smith and J. N. Cooper

New York: McGraw Hill Book Company. (Sixth Edition.) Pp. 671+viii. Price 56s. 6d.

It is difficult to do justice in reviewing a textbook when one has not exact knowledge of the nature of the classes for which it is planned, but the material in this book seems to be dealt with so superficially in many places that it would be almost useless as a manual which would "introduce the student to physics in such a way that he will develop a capacity for seeing relationships between physical phenomena and for applying universal physical principles."

The authors state that in order to maintain appropriate attention to the principles of electricity, they have used only practical units, but the exposition is not exact, fundamental formulae are assumed, yet others are deduced from them. In the chapter on Vector Quantities, vectors are added by "placing the tail of the second arrow at the point of the first"; there is no explanation, no experimental proof. This is typical of the approach throughout, and the physics learnt would rest on no firm foundation. Space which might have been devoted to fundamentals is taken up with tables of data and graphs which might be of use to a research student but not to those "interested in physical science for educational reasons."

It is beautifully produced but would not justify its place on my bookshelf.

K. E. PARKS.

TECHNOLOGY OF INSTRUMENTATION

By E. B. Pearson, F.Inst.P.

London: English Universities Press. Pp. xv+202. Price 25s.

Professor Pearson is to be congratulated on having filled a serious gap in the literature of instrumentation with a book which can be read with profit by the general reader. Modern instrumentation with its feedback systems is a complicated study. The beginner can do no better than to read Professor Pearson's admirably presented introduction.

The scheme of the book is clearly set forth in the chapter headings—Basic Principles of Measurement, Basic Characteristics of Measuring Instruments with a Moving Element, The Dynamic Accuracy of an Instrument, Laboratory Techniques for Measuring the Response Characteristics of Instrument Movements and Simple Servomechanisms, Instrumentation Applied to Process Control, Improvement of Servomechanism Performance, Stability Criteria for Linear Servomechanisms, Components Used in Servomechanism Layouts and Instrumentation of Mathematics. The student is led logically from basic principles to their application in complex equipment and much of the jargon associated with closed-loop control systems is either explained or made unnecessary.

At a time when instrumentation is becoming a major pre-occupation of the industrialist and when the want of well-informed instrument technologists is being felt on all sides, Professor Pearson's book should be of considerable national value.

J. THOMSON.

Forthcoming Institute Meetings

March 19 London and Home Counties Branch

In William Beveridge Hall, Senate House, University of London, 4.30 p.m. Tea 4 p.m.

Joint Symposium with the

Royal Institute of Chemistry (London Section) and

Institute of Biology (London Branch) on

" Science and Society "

Chairman : PROFESSOR P. M. S. BLACKETT, F.R.S.

(*Imperial College of Science and Technology, London*)

Main Speakers :

PROFESSOR L. T. HOGBEN, F.R.S. (*University of Birmingham*)

" Science and its Social Functions "

PROFESSOR A. HADDOW (*Royal Cancer Hospital, London*)

" Science — its Dangers and Promise "

PROFESSOR DAME KATHLEEN LONSDALE, F.R.S. (*University College, London*)

" The Social Place of Scientists "

MR. ANTHONY SMITH ("*Daily Telegraph*," *London*)

" The Deployment of Scientific Effort "

Application for tea tickets must be made on the slip which has been circulated to members of the Branch

March 26, 27 and 28 Stress Analysis Group

In the James Watt Engineering Laboratory, University of Glasgow.

Conference on

" Experimental Stress Analysis "

(Full details and application forms available from the Institute)

March 28 Liverpool and North Wales Branch

In the Department of Electrical Engineering, University of Liverpool, 7 p.m. Tea 6.30 p.m.

" New Methods for Studying the Electronic Structure of Metals "

DR. A. B. PIPPARD, F.R.S.

(*Mond Laboratory, Cambridge*)

April 1 Applied Spectroscopy Group At the Institute's House, 3.00 p.m.

" X-Ray Fluorescence Spectroscopy "

(See page 49 ; admission is by ticket only)

April 9, 10 and 11 Education Group and South Western Branch

In the Department of Physics, University of Bristol

Joint Conference on

" Physics in Schools "

Accommodation will be available in Wills Hall.

(Further details and application forms available from the Institute)

April 11 Scottish Branch In the Carnegie Laboratory of Physics, Queen's College, Dundee, 7.00 p.m.

" Contact Electrification "

DR. P. S. H. HENRY, F.Inst.P.

(*Shirley Institute, Manchester*)

April 16 London and Home Counties Branch At the Institute's House, 6 p.m. Tea 5.30 p.m.

" Heat transfer problems of nuclear reactors "

MR. W. B. HALL

(*U.K. Atomic Energy Authority, Calderbridge*)

April 18 Non-Destructive Testing Group At the Institute's House, 6 p.m. Tea 5.30 p.m.

" High Speed Radiography "

1. Tubes and Mechanisms

MR. R. F. THUMWOOD

(*Queen Mary College, London*)

2. Circuits and Evaluation

MR. R. MEAKIN, A.Inst.P.

(*Armament Research and Development Establishment, Woolwich*)

April 18 Midland Branch At the Union, University of Birmingham

Annual Branch Dinner

(Full details and application forms available from the Institute)

April 18 and 19 X-ray Analysis Group In the College of Science and Technology, Manchester

Spring Conference

(Program and application forms can be obtained from the Institute)

The Institute's Journals

PRINCIPAL CONTENTS OF THE MARCH, 1958, ISSUES

Journal of Scientific Instruments: Volume 35, No. 3

ORIGINAL CONTRIBUTIONS

The Venturi pneumatic pyrometer. By A. M. Godridge, A.Inst.P., R. Jackson, F.Inst.P., and G. G. Thurlow.

An instrument for measuring gas and flame temperatures, is described. From design considerations it is shown that the instrument can be used at higher temperatures than existing probe instruments and has a very rapid rate of response. The operation of the instrument is discussed and examples of its use are given. In the downtakes of open-hearth furnaces and in water-tube boilers the instrument shows advantages over the suction pyrometer in speed of response and freedom from blockage. Results have also been obtained at temperatures higher than those at which any other method of obtaining local temperatures has proved successful.

A nuclear magnetometer. By G. S. Waters and P. D. Francis.

The basic principles of the nuclear free precession magnetometer are briefly described, and full details given of the coils, switching circuits and transistorized amplifying equipment of such a magnetometer. Accuracy of absolute measurement of the earth's total field is $\pm 10\mu G$, and even better when only relative measurements are required. Setting-up of the instrument, which requires no calibration, and taking a reading takes only a few seconds. Suggestions are put forward for possible further applications of the free precession technique.

The emergent column correction in mercury thermometry. By J. A. Hall, F.Inst.P., and Vera M. Leaver.

The conditions which determine the accuracy of measurement of the emergent column temperature when mercury thermometers are used at partial immersion are discussed. The method of measuring the emergent column temperature used at the National Physical Laboratory is described, a table of the average values experienced is given, and the reasons in favour of testing thermometers at the immersion at which they are to be used are explained.

A vibrating condenser manometer. By J. L. Williams, Grad.Inst.P., and G. F. Eveson.

The principle of the use of a vibrating capacitor to measure small displacements has been applied in an instrument to record cyclic fluctuations of air pressure. A summary is made of the results of simple experiments carried out to investigate factors influencing the amplitude of the signal generated by a vibrating capacitor. A description is given of a simple, robust instrument which has been used to measure fluctuating air pressures and reference is made to the characteristics of the instrument.

A simple tensile testing machine for very fine wires. By A. E. Widdowson, A.Inst.P.

A simple machine is described by which stress/strain curves can be obtained for fine tungsten wires as small as 5μ in diameter.

Diffusion measurements by a sampling technique. P. H. Elworthy.

An apparatus has been devised for measuring diffusion coefficients by withdrawing a small sample of the diffusion column and analysing it. The errors normally present in layer analysis methods have been minimized. Providing the volume of the sample was kept within certain limits, and the rate of withdrawal was slow, diffusion coefficients could be measured accurately. The determination of diffusion coefficients of various substances gave values which agreed excellently with known values. The method was precise to 0·4%.

An airflow interrupter for respiratory work. By L. E. Mount.

A respiratory airflow interrupter designed to give information on lung alveolar pressure is described. A slotted rotor moving with a uniform speed of 24 rev./min. inside a slotted sleeve provides 192 interruptions per minute; the sudden pressure change at the mouth on interruption of the airflow is due to equilibration of pressure throughout the lung airways and is determined mainly by alveolar pressure.

Anti-reflexion coatings for indium antimonide and other semi-conductor filters. By S. D. Smith and T. S. Moss.

Several important infra-red filters use semiconductors with refractive indices near 4 (e.g. Ge, PbS, InSb), which have high reflexion losses. Lead chloride is shown to be a good material for "blooming" these semiconductors. Such "blooming" more than doubles the transmission of an InSb filter from 10-13·5μ.

A feedback controlled Pirani gauge. By J. H. Leck, A.Inst.P.

This paper describes a simple feedback circuit for the Pirani gauge in which the power supply to the Wheatstone bridge is adjusted automatically so as to keep the wire temperature approximately constant over a wide range of pressure changes. This is achieved by supplying the power from a d.c. amplifier which is itself controlled by changes in wire temperature, a small fall in temperature serving to increase the power output from the amplifier. A transistor is employed as the input stage of the amplifier. The comparatively large zero drifts in the transistor d.c. amplifier due to temperature changes are no particular disadvantage in this application as the Pirani gauge signal is also dependent upon ambient temperature.

British Journal of Applied Physics: Volume 9, No. 3

SPECIAL ARTICLE

A survey of exo-electron emission phenomena. By L. Grunberg.

"Exo-electron" emission phenomena are reviewed. Kramer's original hypothesis that exo-thermal processes are the cause of the effect is no longer considered valid and it is now widely accepted that particularities of the crystal lattice, such as crystal imperfections are present in surfaces showing electron emission after mechanical deformation, X- or ultra-violet irradiation, electron bombardment, etc. Apparently spontaneous emission during phase changes of metals requires the presence of surface films. Oxygen must be present for emission to occur after the mechanical deformation of metals and photo-electric emission measurements suggest that certain surface oxides then contain negative-ion vacancies (F'-centres). The emission from ionic materials, such as alkali halides depends on the presence of colour centres. The importance of crystal imperfections is brought out by the parallelism between luminescence and exo-electron emission. The latter depends only on the presence of donor-centres, but not on the activator centres necessary

for the former to occur. Various applications of exo-electron phenomena and the question of nomenclature are discussed.

ORIGINAL CONTRIBUTIONS

Aluminosilicates and the high-temperature processing of microwave vacuum tubes. By M. Hillier and R. L. Bell.

The application of high temperature glass techniques to the construction and processing of microwave vacuum tubes is described. An increase in bake-out temperature is shown to have a profound effect on the running pressure, cathode life and other properties which may depend on tube vacua.

The particle size of some Witwatersrand mine dust. By H. St. G. Tucker.

The size distribution of mine drilling dust is examined and the use of Gaudin's relation to describe it proposed. The literature is reviewed and it is inferred that this is the true distribution for any dust of this kind.

The synthesis of single crystals of the sulphides of zinc, cadmium and mercury and of mercuric selenide by vapour phase methods. By D. R. Hamilton.

Experiments with the Reynolds-Czyzack method of growth are described for zinc sulphide and cadmium sulphide. A new application of the method to the crystallization of mercuric sulphide is discussed. Single crystals of mercuric selenide have been produced by a vapour phase reaction and similar experiments attempted with mercuric telluride. The conditions of growth are examined in the light of recent theory ; estimates of surface free energies are obtained.

The low-temperature conductivity of oxide-coated cathodes. By G. S. Higginson.

Measurements of electrical conductivity in the temperature range 300–700° K employing probediodes reveal that, in addition to pore-conduction, at least two conduction processes operate in parallel at temperatures below 700° K. It is suggested that one of these is movement of barium ions over interior crystallite surfaces and the other is electronic conduction limited by electron trapping, e.g. by oxygen, at crystal–crystal interfaces.

The indium-selenium system. By J. C. Brice, Grad.Inst.P., P. C. Newman, A.Inst.P., and H. C. Wright, A.Inst.P.

Polycrystalline specimens of In_2Se_3, InSe and In_2Se were prepared by direct fusion. Electrical and physical measurements were made which indicated a phase change in In_2Se_3 at 196° C.

Temperature and pressure corrections to be applied to the shielded hot wire anemometer at speeds for which natural convective cooling is negligible. By C. F. Cowdrey.

The form of the law of cooling of a shielded hot wire anemometer should not differ greatly from the normal laws of cooling of heated cylinders. By using the law propounded by Hilpert, a method is devised to allow for changes in ambient temperature and pressure when a hot wire anemometer is used at speeds for which the cooling can be considered as entirely due to forced convection. This method is then used to derive the corrections needed in the measurement of air flow over the range of variation of atmospheric conditions normally experienced. However, with slight modifications to allow for changes in the values of the physical constants, it should be possible to use the general method to cover all " perfect " gases at various ambient conditions. A number of experimental results are included in support of the theory. A simple circuit is indicated in the Appendix, based on that outlined by Simmons, by which the useful range of the instrument is greatly increased.

Magnetic anisotropy measurement with an oscillation magnetometer. By J. R. Macdonald.

A method of using an oscillation magnetometer to determine magnetic anisotropy factors in the plane of a thin disk-shaped sample lying in the X—Z plane is described. Both the saturation magnetization, M_0 and the factor $(N_x - N_z)M_0$ may be obtained independently ; N_x N_y and N_z are demagnetization factors which include all contributions to magnetic anisotropy such as those arising from stress, magneto-crystalline anisotropy and shape. These results are correlated with previous work on a somewhat different type of oscillation magnetometer used to determine $(N_y - N_z)M_0$, and it is shown that a correction must be applied for both types of magnetometer when the oscillation amplitude exceeds a degree or two. Finally, it is shown that the oscillation magnetometer can be employed to determine the details of any angular dependence of magnetic anisotropy in the plane of the sample if such anisotropy is sufficiently large. These measurement techniques are particularly applicable to the determination of any dependence of M_0 on film thickness in thin ferromagnetic evaporated films, and to the determination of magnetic anisotropy in thin films evaporated and/or annealed in a magnetic field.

Transfer of tungsten carbide to soft metals during single-traverse and reciprocating sliding. By J. Golden and G. W. Rowe.

This paper describes experiments in which a small radioactive tungsten carbide hemisphere was slid slowly over copper and steel plates. The tungsten carbide transferred to the plates was assessed by counting and autoradiography. On well-prepared copper about 50×10^{-12}g. was transferred steadily to each millimetre of track during a single traversal. This carbide was firmly embedded in the copper, even after several traversals in each direction over the track. Single traversals on mild and stainless steels also produced steady embedded wear. However, when reciprocating traversals were made a considerable proportion of the transferred carbide was scattered loosely on the surface. It is suggested that the difference between the first and subsequent traversals on steels is due to the embedded particles acting as abrasives. It is thus important to distinguish between these two phases of wear.

COMMONWEALTH OF AUSTRALIA

Commonwealth Scientific and Industrial Research Organization

Division of Physics

Appointment No. 770/151 of Chief of Division

Applications are invited for appointment to the position of Chief of the Organization's Division of Physics. The Division is part of the National Standards Laboratories and is situated in the grounds of the University of Sydney.

The Division has the responsibility of maintaining Australian standards of measurement in light, heat and related scientific and technological purposes. In addition it has an active research program in these fields, including thermometry, optics, solar physics and nuclear standards. It has well equipped laboratories and workshop facilities and the present staff includes seventeen Research Officers. The Chief's principal responsibility will be that of broad general supervision and co-ordination of the Division's investigations and he will be expected to develop his own research interests.

A minimum salary of £A3,900 p.a. will be paid, but provision exists for appointment at a higher salary in some circumstances.

Applicants should be scientists of established repute, of professorial standing or its equivalent and must show evidence of research ability combined with considerable powers of leadership.

In the case of an appointee domiciled overseas, first class sea fares to Australia will be paid for the appointee, his wife and family.

The appointment is conditional upon a satisfactory medical examination and the position carries either Superannuation Fund or Provident Account benefits.

Applications quoting Appointment No. 770/151 and stating full name, place, date and year of birth, nationality, marital state, present employment, particulars of qualifications and experience, and of war service, if any, accompanied by copies of not more than four testimonials and the names and addresses of three professional referees should reach the undersigned from whom further particulars may be obtained, by March 29, 1958.

A. Shavitsky
Chief Scientific Liaison Officer.

Australian Scientific Liaison Office,
Africa House, Kingsway,
London, W.C.2.

UNIVERSITY OF GLASGOW

University Studentships and Fellowships

Applications are invited for University Studentships and Fellowships for experimental or theoretical research in Nuclear and Elementary Particle Physics.

Salary scale : Studentships : £350–£500 per annum according to qualifications, with a tenure of three years.

Fellowships : £600–£900 per annum, according to qualifications. Tenure three years on appointment with possible renewal for further period of two years. These Fellowships will be Superannuated under the F.S.S.U.

Applications stating age, academic qualifications, research experience and names of two referees, should be sent to the Professor of Natural Philosophy, The University, Glasgow, W.2, before April 12, 1958.

Birkbeck College

(University of London)

Session 1958/59 begins
Monday, September 29, 1958

Part-time (evening) courses provided for Internal degrees in the Faculties of Arts and Science. Facilities also provided for full-time and part-time students reading for

(i) Higher degrees by thesis in Arts and Science,
(ii) M.A. and M.Sc. Mathematics and M.Sc. Crystallography by examination.
(iii) Academic postgraduate Diplomas in Psychology and Numerical Analysis.

The College also invites applications from full-time and part-time students wishing to take by thesis higher degrees in Statistics.

The Department of Scientific and Industrial Research has accepted the Postgraduate Diploma courses in Psychology and Numerical Analysis, and the M.Sc. Crystallography course, as suitable for tenure of its advanced course studentships. Students intending to read for Higher Degrees in Science by thesis are invited to inquire of the College whether it has available any D.S.I.R. Research Studentships.

Applications for admission to the College should be made before June 1. Pamphlet and form of application may be obtained from the Registrar, Birkbeck College, Malet Street, W.C.1.

UNIVERSITY OF CAMBRIDGE

Department of Engineering

Postgraduate Course in Control Engineering

The 1958-59 Postgraduate course in Control Engineering will begin on October 7, 1958, and will last approximately nine months. This is the fourth course of a series which has been established in order to meet the need of industry for men trained to a high standard in the theoretical principles and practical application of automatic control and to afford opportunity for study of advanced techniques and modern development in the general field of Control Engineering.

The number of students will be limited and applications must reach the Secretary of the Department not later than July 1, 1958. Candidates should hold a degree in Engineering or a suitable alternative qualification and have had some practical training and experience. They will be required to attend for interview in Cambridge on or before August 15, 1958.

Further details and forms of application for admission may be obtained from the Secretary, Cambridge University, Department of Engineering, Trumpington Street, Cambridge.

QUALIFIED PHYSICIST required for a post which involves a study of the deposition of pure materials produced by thermal and other decomposition techniques. Experience in high vacuum work and also in R.F. heating units would be an advantage. The post is of a senior nature. Please apply to the Deputy Research Manager, The Plessey Co. Ltd., Caswell Research Laboratories, Towcester, Northants.

CENTRAL ELECTRICITY GENERATING BOARD

RESEARCH LABORATORIES

LEATHERHEAD, SURREY

require Physicists for work on X-ray diffraction. Candidates should possess a degree or equivalent. Experience in X-ray crystallography or, alternatively, an interest in this field with some research experience is desired. Salaries within scale £1,055–£1,265 per annum and £820–£995 p.a. according to experience and qualifications. Write for application form to I. G. Ellis, Personnel Officer, 24/30 Holborn, London, E.C.1, quoting reference PB/52.

BRITISH PETROLEUM CO. LTD., has vacancies for Geophysicists on its exploration staff. Candidates who should have some experience in the field and must have an honours degree in physics with subsidiary mathematics and/or Geology. Basic salary is commensurate with age and experience, commencing at £1,130 for young inexperienced graduates. Appropriate allowances are paid on foreign service. Generous pension scheme. Written applications, quoting reference F.533 should be addressed to Personnel Manager, British Petroleum Co. Ltd., Britannic House, Finsbury Circus, London, E.C.2.

McMASTER UNIVERSITY

POST-DOCTORAL FELLOWSHIPS IN PHYSICS

Applications are invited for National Research Council and other Post-Doctoral Fellowships tenable in the Department of Physics, McMaster University. Successful applicants may choose to work full-time on their research or to supplement their research with a modest amount of lecturing. Inquiries and applications should be addressed to Professor H. E. Duckworth, Chairman, Department of Physics, McMaster University, Hamilton, Ontario, Canada.

A GRADUATE PHYSICIST is required to conduct research into physical problems associated with the use of tungsten in lamps and valves. Previous experience in high vacuum techniques would be an advantage. Applicants are invited to write to the Director of Research, The British Thomson-Houston Co. Ltd., Rugby, stating age, qualifications, experience and quoting reference JSJ.

PHYSICIST, graduate, preferably of honours degree standard required by the Research Laboratories of British Insulated Callenders Cables Ltd., Shepherds Bush, London, W.12. The work involves research and development on dielectrics and capacitors. Experience in vacuum-metallizing or ceramics would be an advantage. Five day week. Pension Fund. Applications giving details of age, qualifications and experience should be made to the Personnel Officer, 38 Wood Lane, London, W.12.

Chartered Patent Agents

W. H. BECK, GREENER & CO.

7 Stone Buildings,
Lincoln's Inn,
Chancery 2535 London, W.C.2

IMPERIAL CHEMICAL INDUSTRIES LTD.

Billingham Division

Vacancies for

PHYSICISTS

Imperial Chemical Industries Ltd., Billingham Division, has several interesting vacancies for PHYSICISTS, to participate in research work in MECHANICAL ENGINEERING. In this department modern physical techniques are being applied to the investigation of vibration and noise control, friction and lubrication, stress analysis, and mechanics of engineering plant.

Candidates for these senior appointments should hold a good honours degree, and it is desirable that applicants should be able to show evidence of interest in one or other of these fields.

Imperial Chemical Industries Ltd. is noted for its progressive staff policy which offers :

Attractive salary and profit-sharing schemes

Pension fund, subsidized canteens, excellent social and game facilities.

Assistance with house purchase and removal expenses for married men.

Write, giving brief details of age, qualifications and experience, to the Staff Manager, Imperial Chemical Industries Ltd., Billingham Division, Billingham, Co. Durham, quoting reference W/1/5.

Appointments Vacant

The inclusion of particulars of a vacancy must not be taken to imply that the Institute necessarily approves of the terms offered or that might be offered. Candidates should satisfy themselves that these are satisfactory, and they may always refer to the Institute for advice.

PHYSICIST. Iraq Petroleum Co. Ltd., requires a Physicist for work in its Reservoir Engineering Laboratory in London on the analysis of reservoir performance with the aid of electric analogue computers. Applicants should have a good honours degree and some experience of electronics.
The selected candidate will be required to spend a short initial period in the Middle East to acquaint himself with the background of the work he will be doing in London. Age range 25-30. Salary will be assessed according to age and experience but will not be less than £800 per annum at 25. There is a pension scheme and luncheon club in the building. Write in full to Staff Manager, Iraq Petroleum Co. Ltd., 214 Oxford Street, London, W.1.

UNIVERSITY OF MALAYA

Applications are invited for (i) Lectureship or (ii) Assistant Lectureship in Physics. Salary scales : (i) £1,148 × 49–£1,442/£1,540 × £56–£1,820 p.a., (ii) £1,001 × £49–£1,099 p.a. Entry point according to qualifications and experience. Allowances : expatriation in range £280–£308 p.a., cost of living in range £210–£560 p.a. Passages for appointee, wife and children under 12 years. Part-furnished quarters at reasonable rent. Provident Fund scheme. Detailed applications (six copies) naming three referees by April 30, 1958, to Secretary, Inter-University Council for Higher Education Overseas, 29 Woburn Square, London, W.C.1, from whom further particulars may be obtained.

PHYSICIST

AUTOMATIC TELEPHONE & ELECTRIC CO. LTD., LIVERPOOL,
have a vacancy for a qualified PHYSICIST for their Laboratories at their Main Works at Liverpool.

Candidates should be of graduate standard or equivalent, with reasonable knowledge of Chemistry and the work is on projects involving insulating materials, dielectrics, and applied industrial physics. Not less than two years' experience in this field is desirable.

The post will be on the permanent staff, with generous Contributory Pension Fund.

Full particulars of age, qualifications and experience should be sent to :—
THE PERSONNEL MANAGER,
A.T. & E. CO. LTD.,
STROWGER WORKS, LIVERPOOL.

BRISTOL EDUCATION COMMITTEE

COLLEGE OF TECHNOLOGY

The Governors invite applications for following posts in Department of Physics and Mathematics :

LECTURERS (three) IN MATHEMATICS

Applicants must possess Honours degree in Mathematics or Engineering with industrial or research experience involving applications of mathematics to engineering or scientific problems.
Experience in statistical work required in one post.

LECTURER IN PHYSICS

Applicants must possess Honours degree in Physics and industrial or research experience in a branch of applied physics, preferably Electronics or Nuclear Physics.
Salary : (Men) £1,200 × £30–£1,350.
(Women) £960 × £24–£1,080 with equal pay adjustment.
Consideration given to previous experience in fixing initial salary.
Application forms and details from Registrar, College of Technology, Bristol, 7.

HUDDERSFIELD COLLEGE OF TECHNOLOGY

PRINCIPAL : DR. W. E. SCOTT, M.B.E.

DEPARTMENT OF PHYSICS

Required as soon as possible Grade B Assistant to teach Physics. The salary (Burnham scale) rises to a maximum of £1,025 (£820 for Women plus the gradual introduction of equal pay) plus allowances for graduate status (£75 or £125—men ; £60 or £100—women) and training (£25 to £75—men ; £20 to £60—women). The commencing salary will depend upon qualifications and experience and may include up to 12 increments in respect of approved service in industry.
Further particulars and forms of application, which must be returned as soon as possible, obtainable from the Principal, College of Technology, Queen Street South, Huddersfield.

H. Gray,
Chief Education Officer.

UNIVERSITY OF ABERDEEN

NATURAL PHILOSOPHY DEPARTMENT

Applications are invited for the following posts :
Experimental Physics—Senior Lecturer or Lecturer and Assistant.
Theoretical Physics—Lecturer and Assistant.
Salary scales : Senior Lecturer, £1,650–£2,150
Lecturers, £900–£1,650
Assistants, £700–£850.
Placing according to qualifications and experience. F.S.S.U. and child allowance.
Particulars from the Secretary, The University, Aberdeen, with whom applications should be lodged by April 18, 1958, as follows :
Senior Lecturer and Lecturer—eight copies.
Assistants—two copies.

BRITISH THOMSON-HOUSTON CO., LTD.

The British Thomson-Houston Co. Ltd., invites applications for posts in its Research Laboratory at Rugby in an expanding research group working on a number of interesting physical problems.

(i) A physicist or physical chemist to carry out experimental work on the relations between gases, ionized gases and solids.

(ii) A mathematician or physicist to carry out mathematical investigations, mainly on problems connected with gas discharges.

Applicants should have good honours degrees, some knowledge of low pressure techniques would be useful but not essential for (i), and some knowledge of digital computer techniques for (ii). The successful applicants will, however, have ample opportunity to acquire and expand their knowledge of these and other techniques. Applicants are invited to write to the Director of Research, The British Thomson-Houston Co. Ltd., Rugby, giving details of age, qualifications, etc., and quoting reference CAM.

BRITISH THOMSON-HOUSTON CO. LTD.

The British Thomson-Houston Co. Ltd., has vacancies in its Research Laboratory at Rugby for physicists with good honours degrees to work on new semi-conducting materials, studying their fundamental properties and the development of devices. Experience in this field is not essential and new graduates are invited to apply. Successful applicants will form part of a small expanding research team with excellent opportunities for original research ; publication of papers is encouraged. Applicants are invited to write to the Director of Research, The British Thomson-Houston Co. Ltd., Rugby, giving details of age, qualifications, etc. and quoting reference WI.

UNIVERSITY COLLEGE OF RHODESIA AND NYASALAND

Applications are invited for Lectureship in physics. Salary scales : Assistant Lecturer £1,050 × £50–£1,200 p.a. Lecturer (Grade II) £1,200 × £50–£1,450 p.a. (Grade I) £1,450 × £50–£1,750 p.a., entry point determined by qualifications and experience. Superannuation scheme. Passages to Salisbury for appointee, wife and dependent children on appointment with allowance for transport of effects. Unfurnished accommodation at rent of up to 15 per cent of salary.

Detailed applications (six copies) naming three referees by May 20, 1958, to Secretary, Inter-University Council for Higher Education Overseas, 29 Woburn Square, London, W.C.1, from whom further particulars may be obtained.

SOUTH AFRICAN COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH—Vacancy for a Spectrochemist at the National Physical Research Laboratory, Pretoria. Minimum qualifications : Doctorate in physics or physical chemistry with three years' post doctorate research experience. The Division is concerned with fundamental and applied research. Salary and allowances in range £1,080–£1,854. Free passage. Apply further information : South African Scientific Liaison Office, Africa House, Kingsway, London, W.C.2.

COMMONWEALTH OF AUSTRALIA

Commonwealth Scientific and Industrial Research Organization

Division of Industrial Chemistry

Appointments to Research Staff

The Organization's Division of Industrial Chemistry, located at Melbourne, Victoria, wishes to appoint two Research Chemists to take part in the program of its Organic Chemistry Section.

The appointees will be required to work on one of the following topics :

(*a*) Some aspects of aliphatic chemistry, e.g. the oxidation of long-chain compounds, particularly when absorbed on surfaces. Promising results have already been obtained in this work (Reference No. 590/664).

(*b*) Elucidation by X-ray or other physical means of the molecular structure of organic compounds isolated as the result of researches in the Organic Chemistry Section. Normally the compounds concerned will be natural products, whose structures have proved difficult to determine by chemical degradation (Reference No. 590/665).

Applicants for both positions should possess a University honours degree in science with specialization in organic chemistry for appointment (*a*) and in chemistry or physics for appointment (*b*), together with at least two years' research experience in both cases.

Commencing salaries will be determined according to the appointee's qualifications and experience and will be within the salary range of Research Officer, £A1,313–£A1,938 p.a., or Senior Research Officer £A2,048–£A2,323 p.a.

Appointment to position (*a*) may be made for a fixed period of three years or on a long-term basis depending largely on the wishes of the successful candidate. Appointment to position (*b*) is for three years only in the first instance. In the case of appointees domiciled overseas, first class sea fares to Australia will be paid for the appointee, his wife and family. If appointments are made for short-term periods return fares will also be paid.

The appointments are also conditional upon satisfactory medical examinations and if indefinite appointments are made the appointees will be required to contribute to, and be eligible to receive benefits from, either the Commonwealth Superannuation Fund or the Commonwealth Provident Account.

Applications quoting the appropriate Appointment No. and stating full name, place, date and year of birth, nationality, marital state, present employment, particulars of qualifications and experience, and of war service, if any, accompanied by the names of three professional referees should reach the undersigned from whom further particulars may be obtained, by April 25, 1958.

A. Shavitsky,
Chief Scientific Liaison Officer.

Australian Scientific Liaison Offices,
Africa House,
Kingsway, London, W.C.2.